



NIKON RESEARCH CORP. OF AMERICA

# ArF Lithography Extension

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Sr. Research Scientist

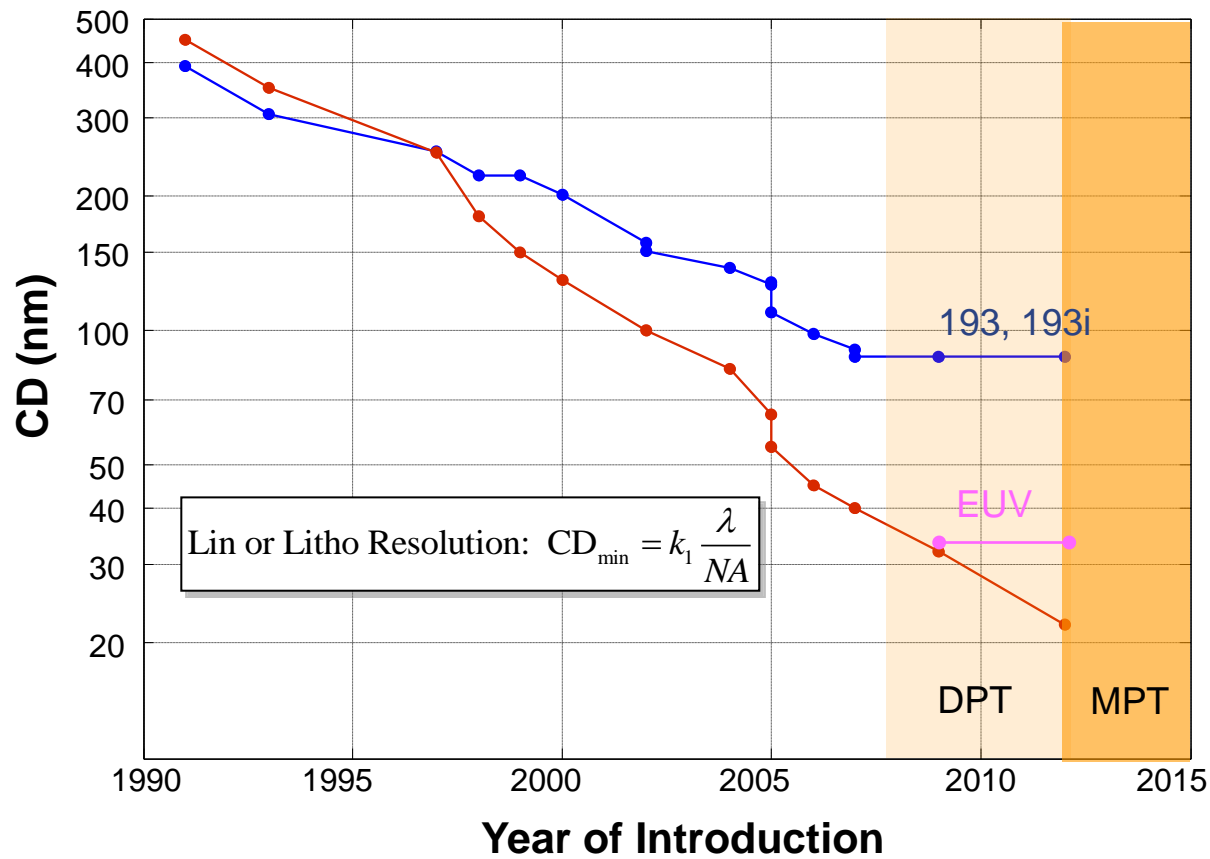
# Where We Are Now



**Smooth so far, but not a lot of landmarks to guide us ...**

# Challenge 1: Resolution

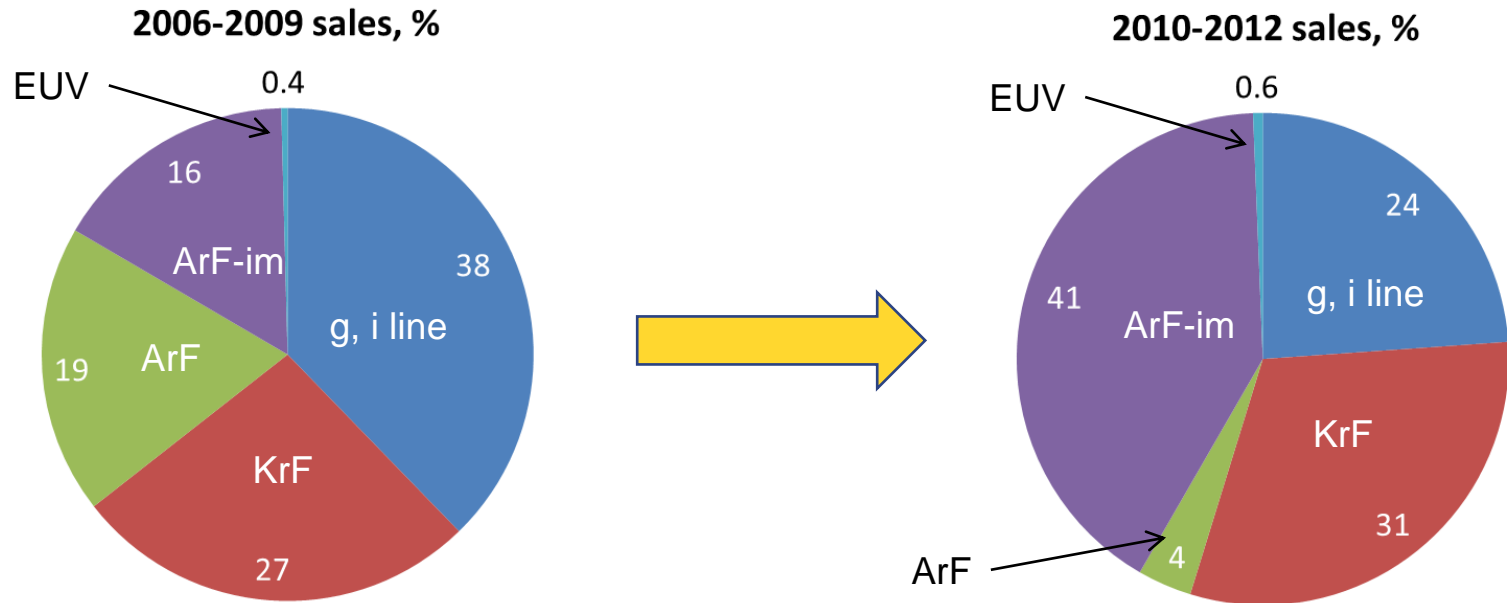
## Resolution vs. Year of Introduction



# The Revolution Has Been Postponed



- You can still count the worldwide EUV tools on your fingers...



... mostly due to infrastructure issues.

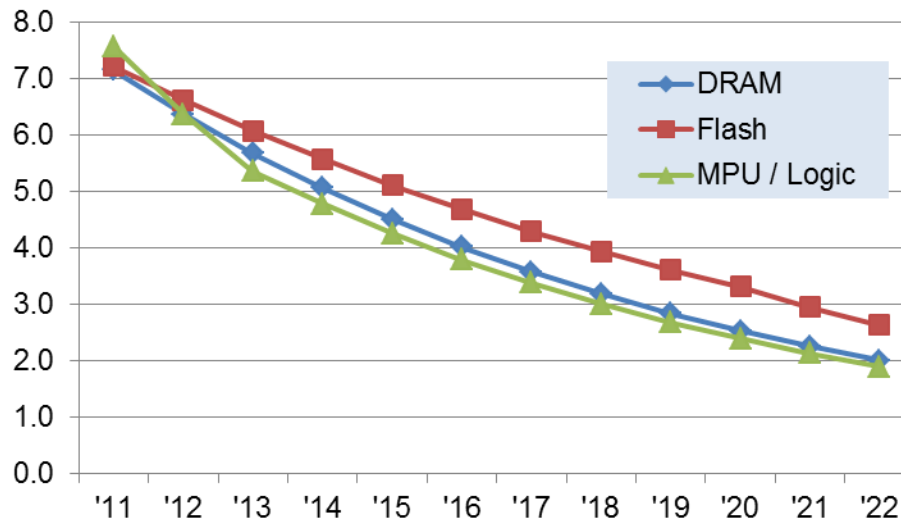
*Data from Gartner Mar 2013*

- Nikon believes that resolution answers will be
  - Spacer-assisted pitch division
  - Complementary litho
  - “Exotic” solutions like directed self-assembly

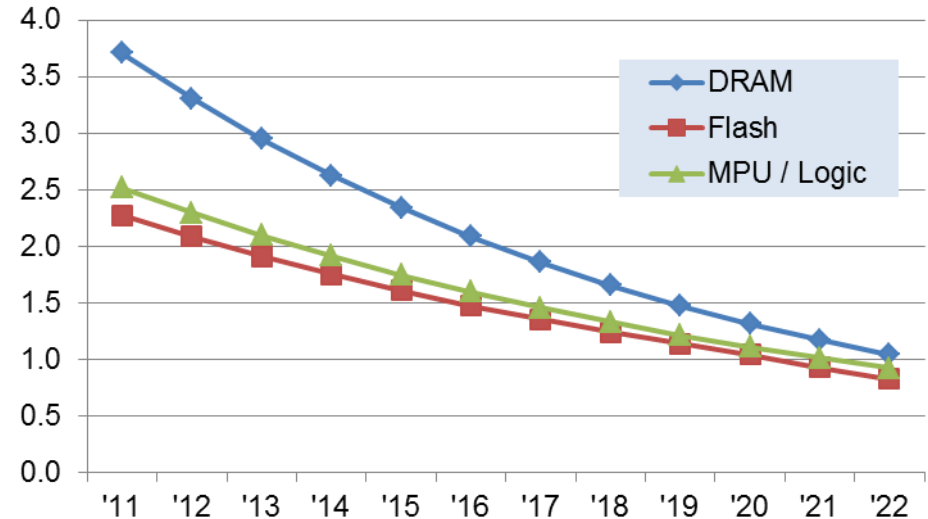
# Challenge 2: “Power is Useless w/o Control”



## Mix-Match Overlay



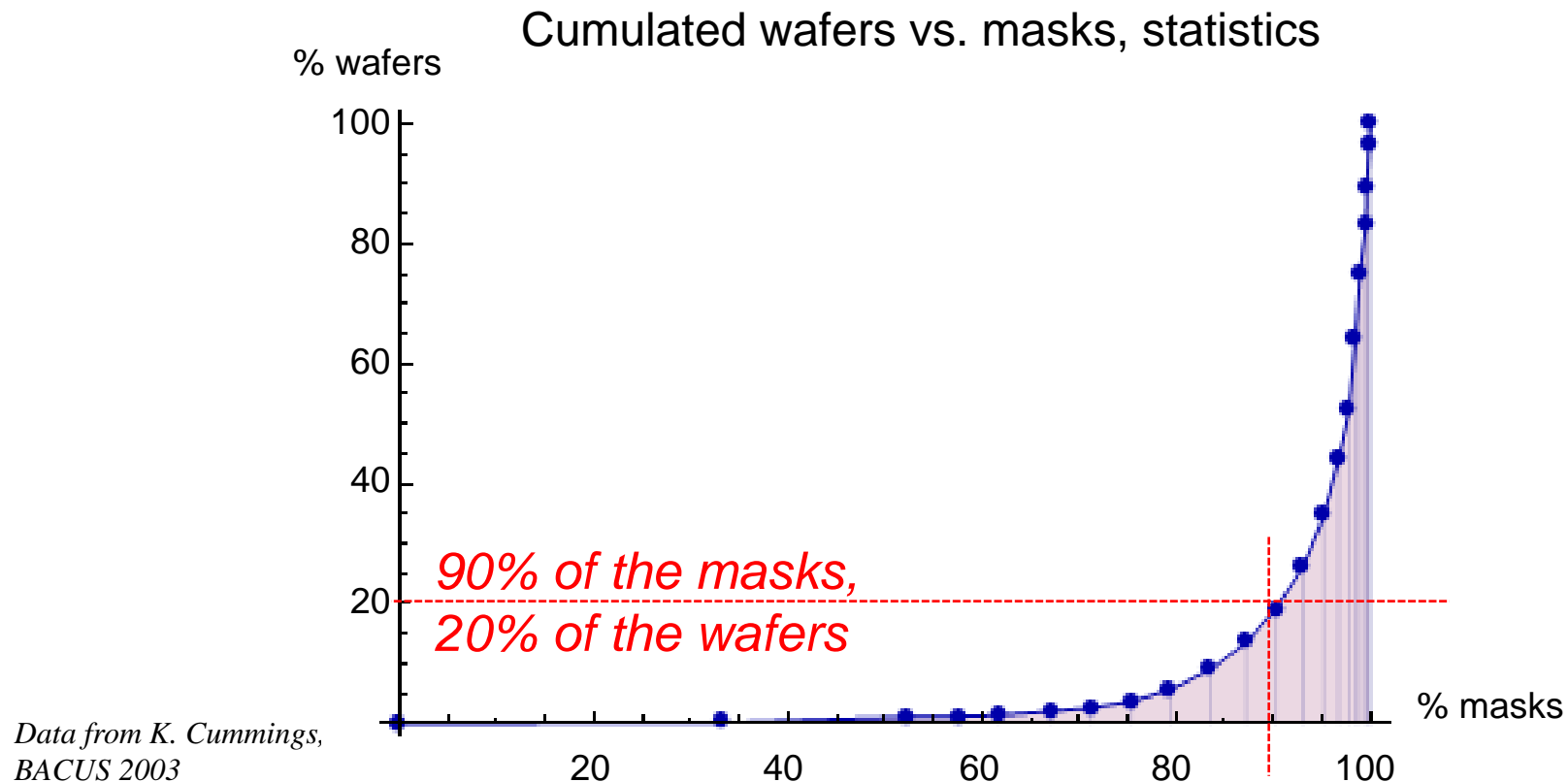
## CD Control



**Control requirements, i.e. CDU and Overlay, can *individually* limit the evolution of litho technology**

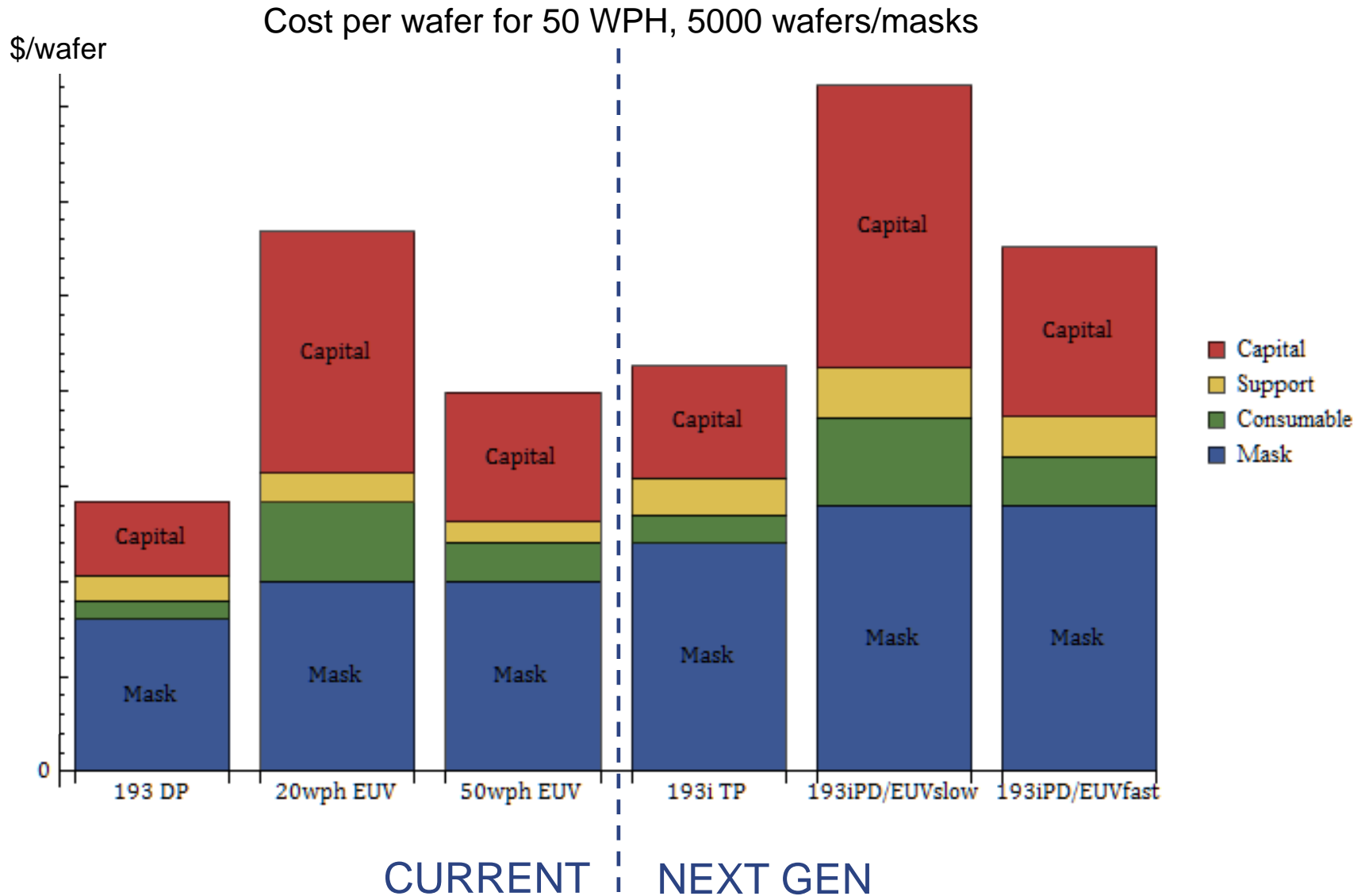
# Challenge 3: Flexibility

- Foundry mask use:



**Scanners need to respond to customers' needs on the fly**

# Challenge 4: Cost

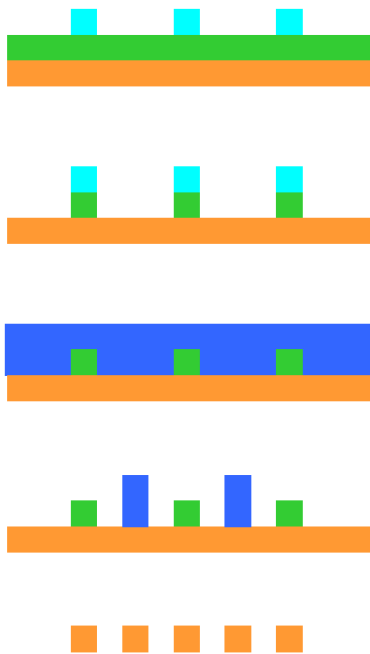


# Pitch Division: 193i is Doing This Now

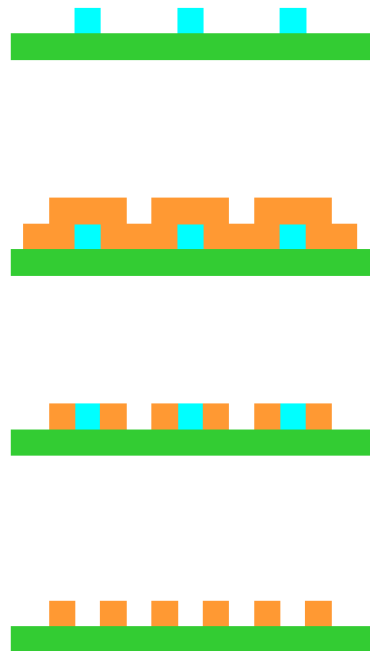


## Printing the Grating

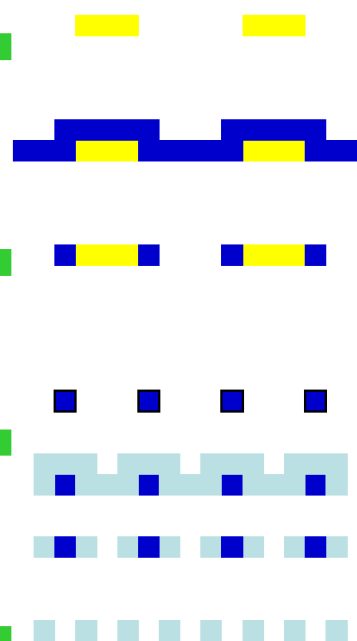
Double Patterning  
Pitch Division (DPPD)



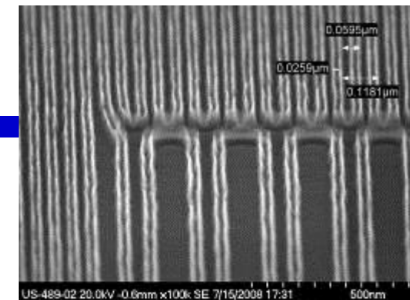
Spacer Based  
Pitch Halving (P/2)



Spacer Based  
Pitch Quartering (P/4)



25P



P/6  
P/8

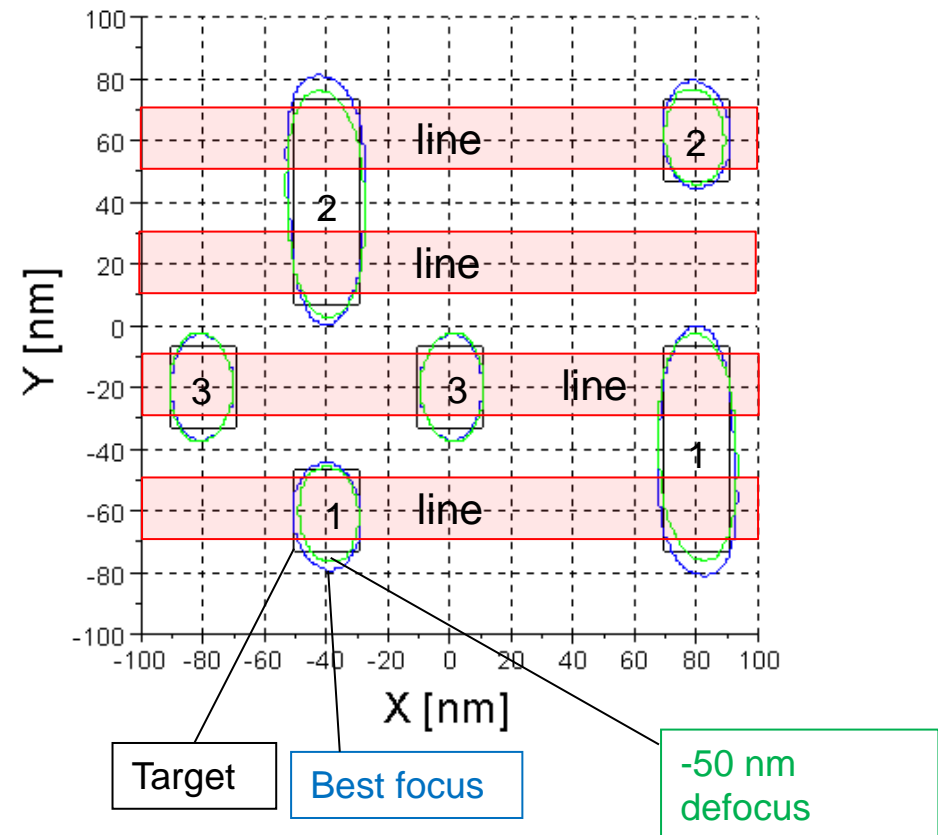
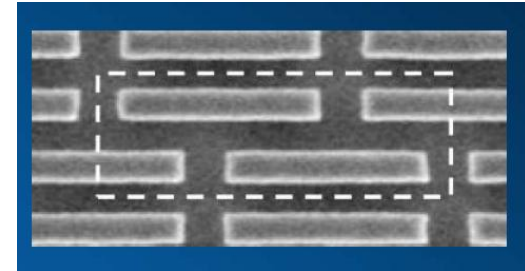
ArF Extension can deliver grating pitches for foreseeable future





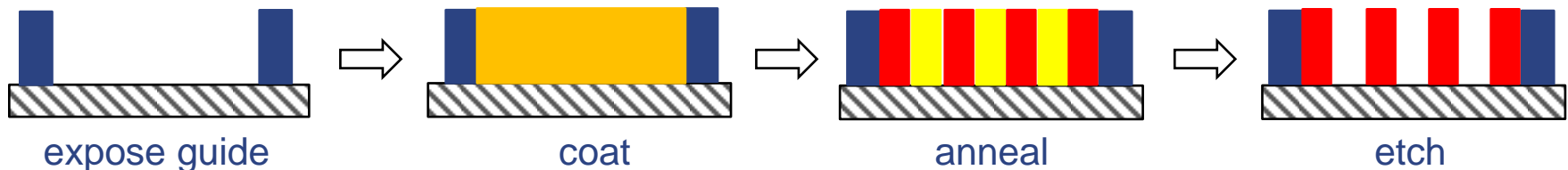
# Complementary Litho

- Combine spacer MP with a trim mask or “cutting” exposure
- Clever design decomposition reduces the number of masks needed
- Candidates for cut exposure:
  - Electron beam
  - EUV
  - 193i



# Pitch Multiplication with DSA

- Print a guide structure with the 193i tool
  - Graphoepitaxy: make a fence
  - Chemoepitaxy: paint stripes
- Coat with the block copolymer material and anneal



L/S or contact holes created as if by magic

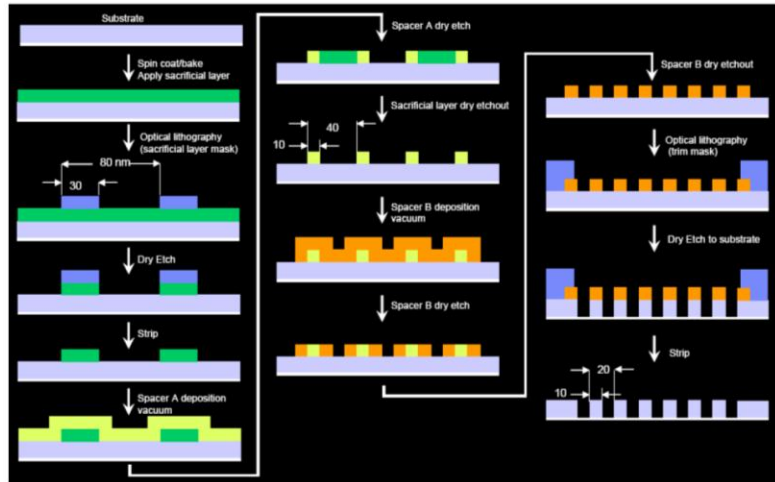
- 25 nm pitch L/S
- 29 nm contacts

**DSA is a natural partner with 193i lithography**

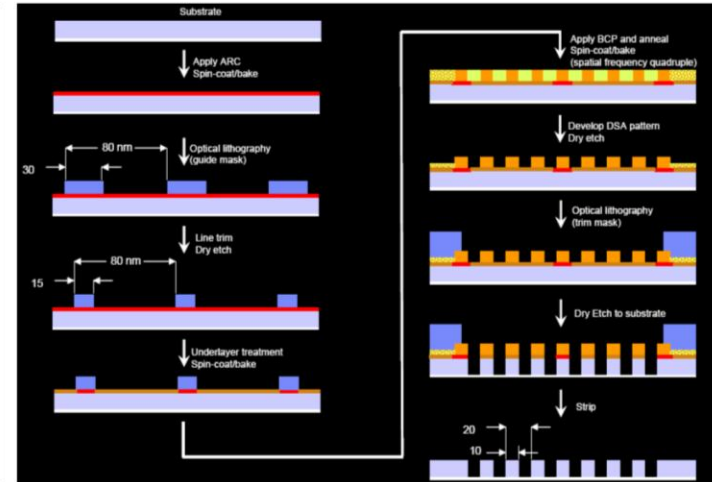
# Comparing Pitch Multiplication

## DSA Vs. Spacer Quadruple Patterning

Quadruple Patterning Spacer Pitch Division process

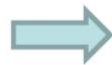


DSA frequency quadrupling process



1 spin coat/bake (excl. litho)  
2 exposure steps  
2 strip steps  
2 vacuum depositions  
5 dry etch steps

1 population of line CDs  
4 populations of space CDs



+2 spin coat/bake  
-1 strip step  
-2 vacuum depositions  
-2 dry etch steps

-3 populations  
of space CDs



3 spin coat/bake (excl. litho)  
2 exposure steps  
1 strip step  
0 vacuum depositions  
3 dry etch steps

1 population of line CDs  
1 population of space CDs

(Hinsberg/Cheng/Kim/Sanders, IBM 2010)

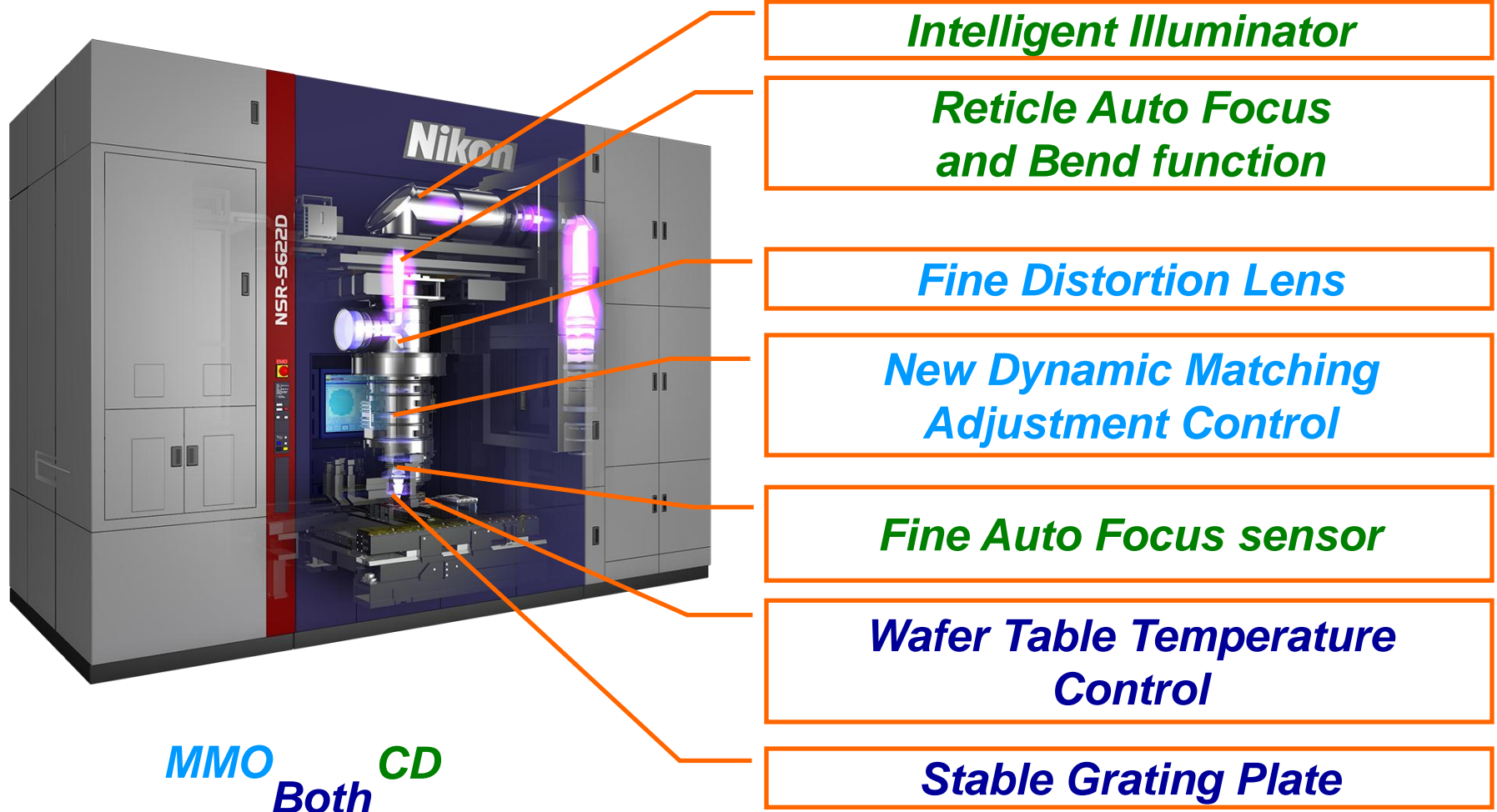
# Will the Scanner Support These Techniques?



Technique	Key Scanner Requirements
Spacer DP	<ul style="list-style-type: none"><li>• Overlay &lt;4 nm</li></ul>
“True” double patterning	<ul style="list-style-type: none"><li>• Overlay ~2 nm</li><li>• Excellent CDU</li></ul>
Multiple patterning	<ul style="list-style-type: none"><li>• Continue reducing overlay and CDU</li></ul>
DSA	<ul style="list-style-type: none"><li>• Focus and dose control similar to current processes, depending on DSA method</li><li>• Overlay similar to spacer DP</li><li>• CDU around 2 nm for guide patterns</li></ul>
Complementary litho	<ul style="list-style-type: none"><li>• All or most of the above</li></ul>

- Performance:
  - Autofocus and CDU performance
  - Mix-and-Match Overlay
  - Intelligent Illuminator for custom illumination design and SMO
- Flexibility via support software:
  - Imaging Master
  - CDU Master
  - Overlay Master
- Cost reduction via productivity:
  - Increased throughput
  - 450 mm support
- Compatibility with other NGL solutions like Directed Self Assembly

# Streamalign Platform Evolution: S622D



*Intelligent Illuminator*

*Reticle Auto Focus  
and Bend function*

*Fine Distortion Lens*

*New Dynamic Matching  
Adjustment Control*

*Fine Auto Focus sensor*

*Wafer Table Temperature  
Control*

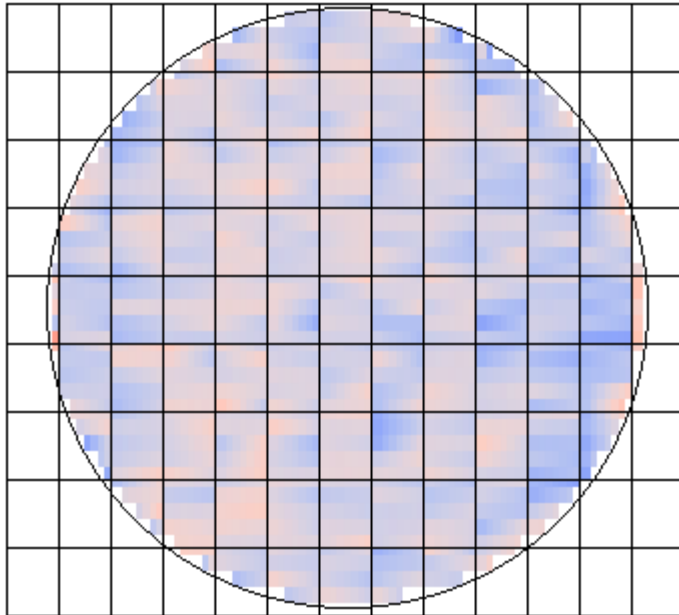
*Stable Grating Plate*

**MMO** **Both** **CD**

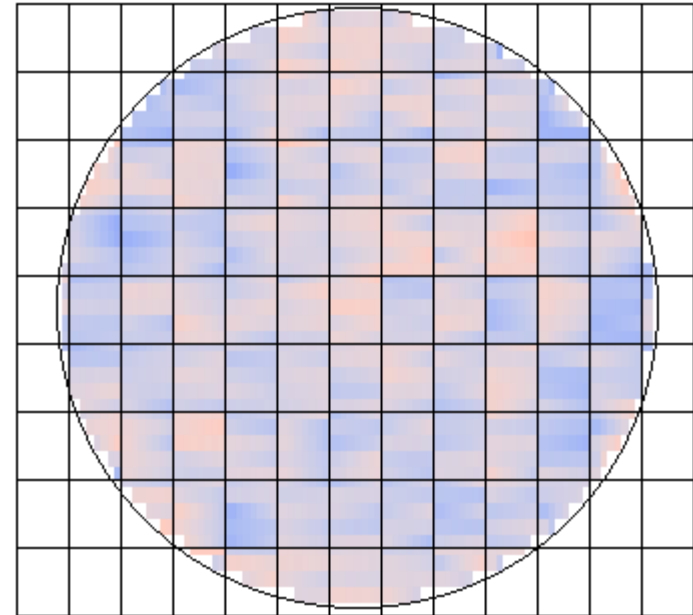
**Meets next-generation overlay and CDU requirements**

# S622D Focus Uniformity (PSFM)

**S621D**



**S622D**



<b>All shot <math>3\sigma</math> :</b>	<b>11.3 nm</b>
<b>Perfect shot <math>3\sigma</math>:</b>	<b>10.5 nm</b>
<b>Edge shot <math>3\sigma</math>:</b>	<b>13.2 nm</b>

<b>All shot <math>3\sigma</math>:</b>	<b>10.6 nm</b>
<b>Perfect shot <math>3\sigma</math>:</b>	<b>10.3 nm</b>
<b>Edge shot <math>3\sigma</math>:</b>	<b>11.2 nm</b>

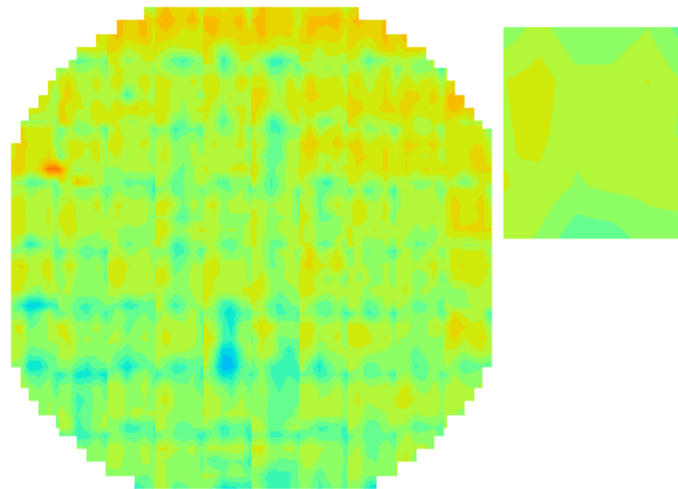
# S622D CD Uniformity

- LNA1.350/Sigma 0.163 Annular
- L32 nm/P90 nm

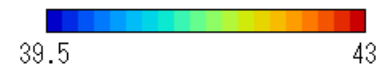
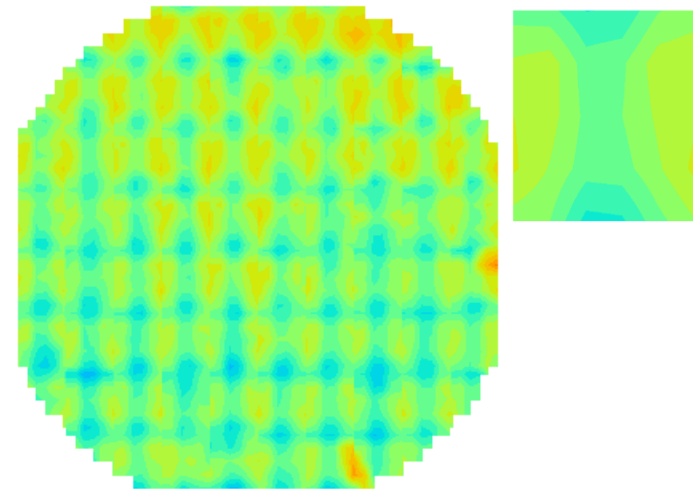
Horizontal		Vertical	
Inter Shot	Intra Shot	Inter Shot	Intra Shot
0.41	0.44	0.36	0.69

[nm]

Horizontal



Vertical





# Overlay Capability (Single Wafer)

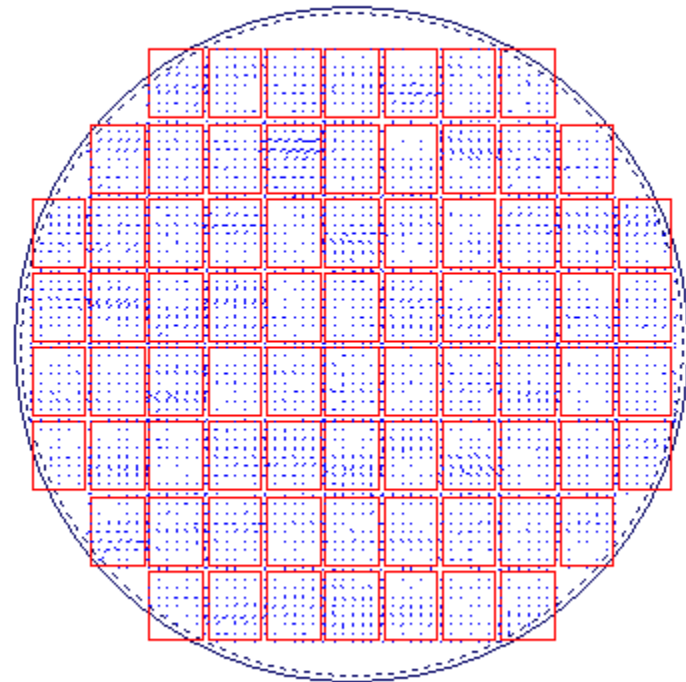
Condition:

- S622D
- 700 mm/sec scan
- machine #1

	X	Y
$3\sigma$	0.70	0.69

 [nm]

Vector map of S622D



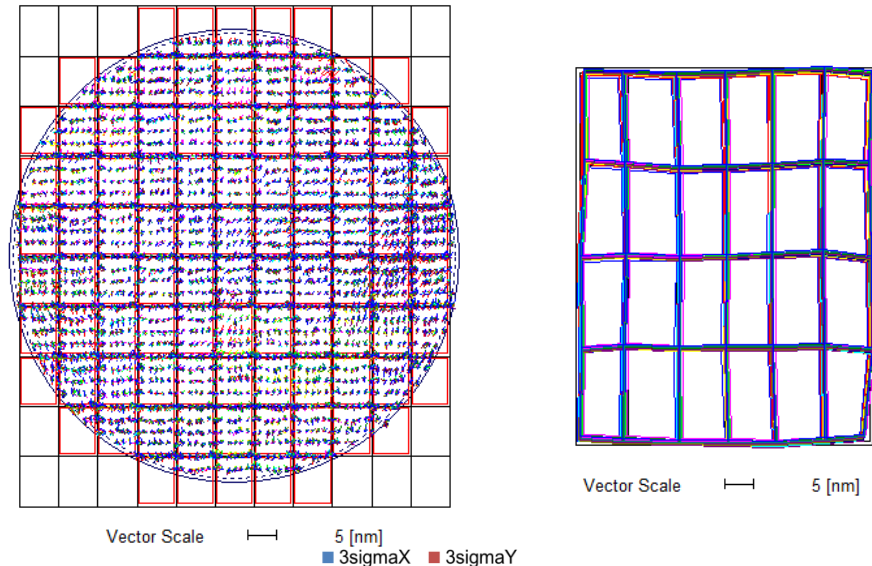
Vector scale :  3 nm

Single-machine overlay below 1 nm

# S622D Mix-and-Match Overlay

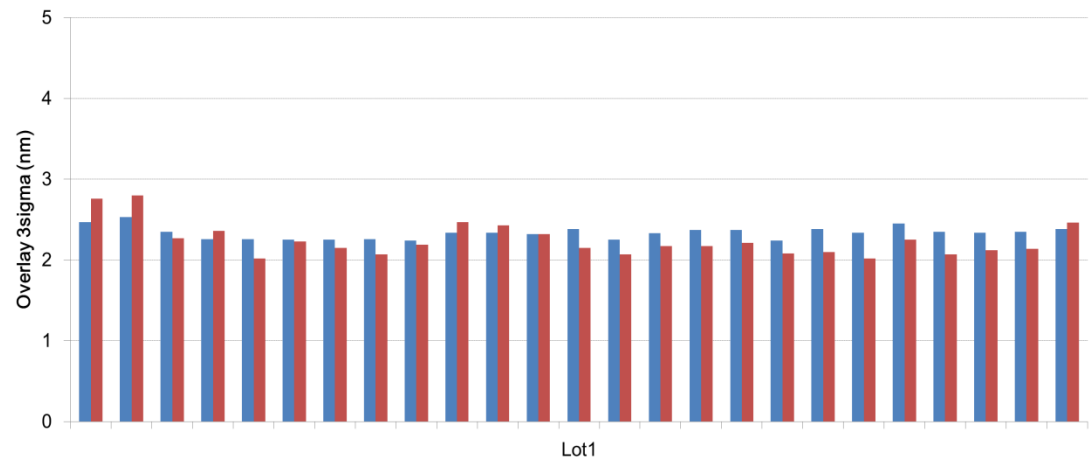
Condition:

- 1<sup>st</sup> exposure: S622D#1
- 2<sup>nd</sup> exposure: S622D#2
- 700 mm/sec scan
- Mix and Match function
  - SDM
  - MLGCM



Ave.+3 $\sigma$	X	Y
SMO	1.71	1.93
Distortion	1.84	1.47
Grid	0.57	0.49
<b>MMO(total)</b>	<b>2.58</b>	<b>2.47</b>

[nm]



**MMO 3 nm or less**

# Software Support for Flexibility



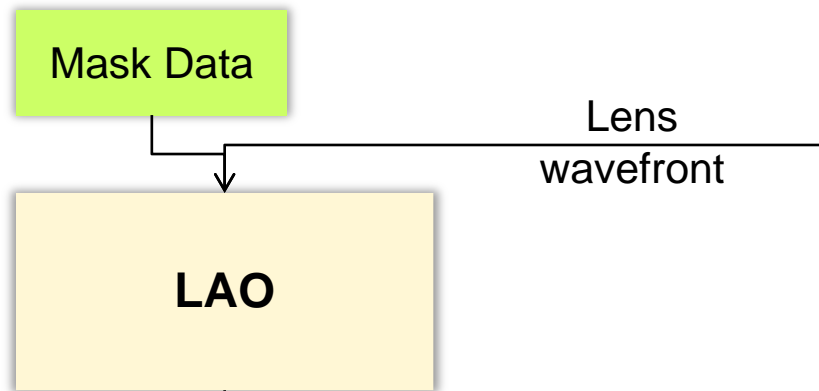
- *Some reticle patterns are sensitive to particular lens aberrations*  
⇒ Solution: **Imaging Master: Lens Aberration Optimizer**
- *Exotic illumination patterns heat the lens in odd ways*  
⇒ Solution: **Imaging Master: Thermal Aberration Optimizer**
- *External process effects limit scanner CDU performance*  
⇒ Solution: **CDU Master**
- *Mask or other errors prevent full realization of optimum PW*  
⇒ Solution: **Global Source Optimization**
- *Double patterning or DSA require tighter overlay across fab*  
⇒ Solution: **Overlay Master**

# Flexibility: LAO and ThAO Optimization



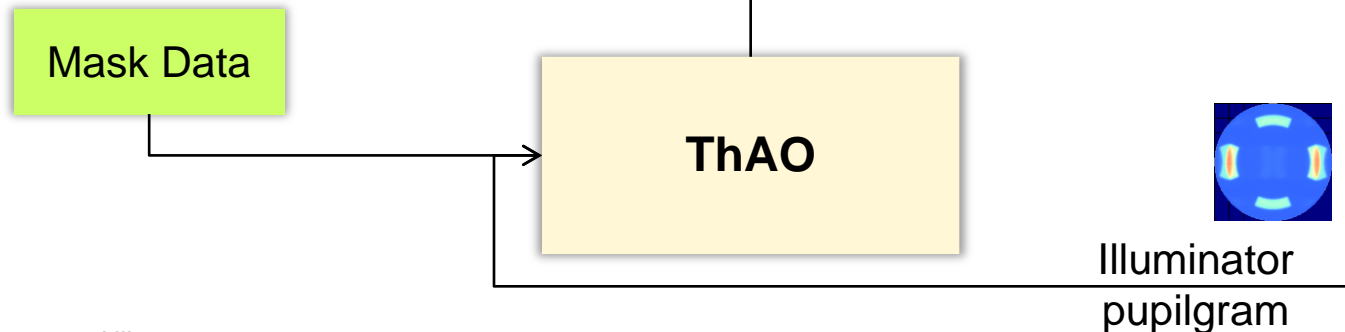
- **Lens Aberration Optimizer:**

- reticle-specific lens adjustment

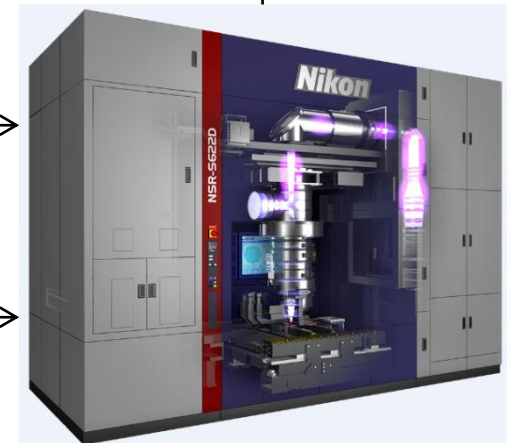


- **Thermal Aberration Optimizer:**

- reticle-specific lens heating control



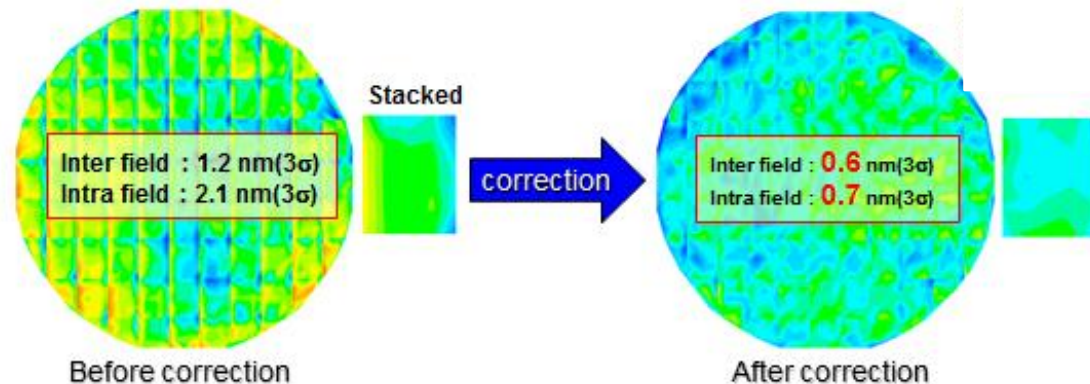
*Reticle bend,  
reflex mirror adjust,  
lens iMAC adjust*



## ■ CDU Master:

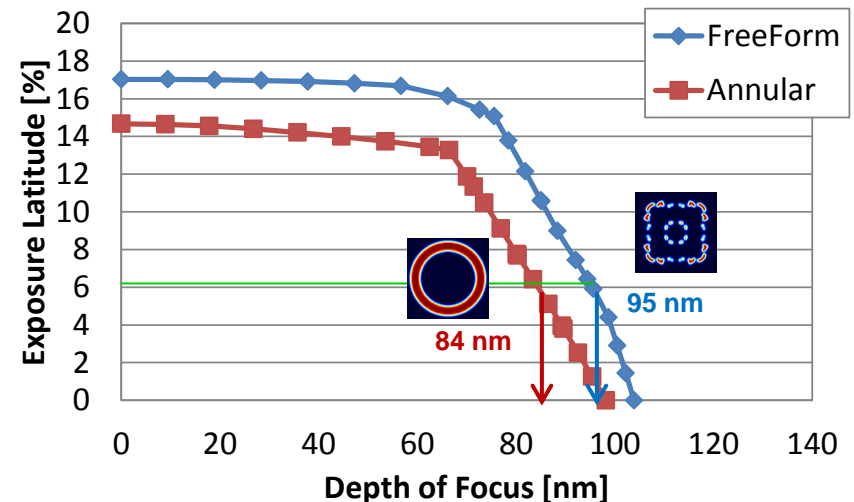
- measures test wafer
- makes dose and focus corrections to reduce CD error from elsewhere

## CDU Correction Result



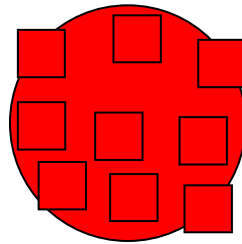
## ■ Source Global Optimization:

- Uses freeform Intelligent Illuminator
- SO after the mask is made
- Improves process window with minimal OPE effect

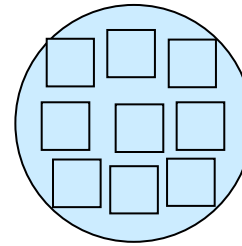


# Overlay Master

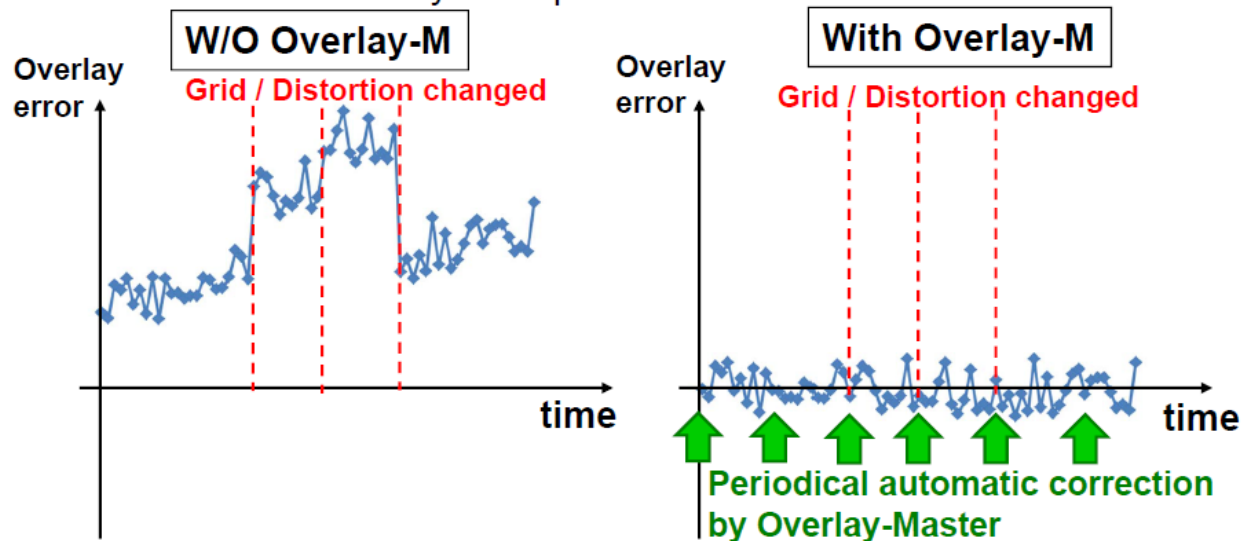
## *Periodic grid parameter optimization and auto setting*



Grid Error



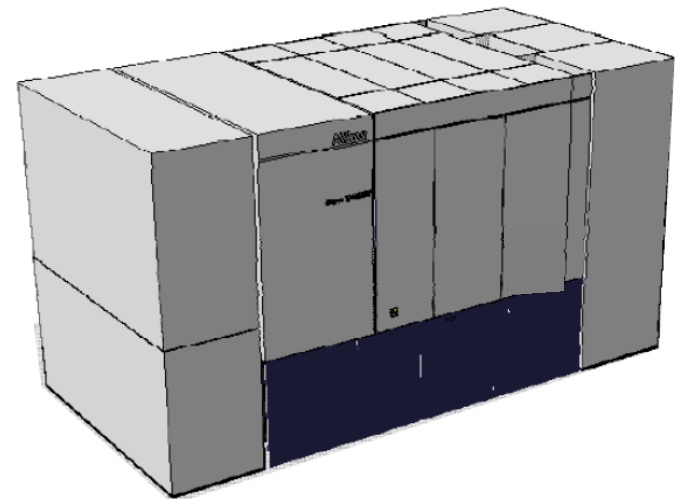
Adjust the grid relative to the Monitor wafer



# Reducing Cost: 450 mm Plans



- Nikon will leverage our experience from the transition to, and the standardization, of 300 mm wafers
  - making use of collaboration of chipmakers, suppliers, and consortia
- Nikon leading tools S621/S622D(immersion), and S320F(dry) have high overlay accuracy and throughput
  - The proven *Streamalign* Platform is effective in accommodating 450 mm wafers
- By 2015, Nikon plans to ship early learning tools based on 193 nm immersion for 450 mm



**Nikon plans to ship 450 mm HVM tools in 2017 through our joint development effort with a chipmaker**



# The Path is Clear. Nikon 193i Will...



- Enhance resolution with multiple patterning, complementary litho, and linking with NGL solutions
- Provide control by improving the *Streamalign* platform
- Allow flexibility with a package of software solutions
- Reduce cost with 450 mm wafer use